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Accelerate Your TransWarp GS Card — Part 1

by John Link

Over the years I have developed a healthy respect for the design and reliability of the Applied Engineering TransWarp GS (TWGS) accelerator card in my computer. The card works well and more than doubles the processing speed of my system.

Now, with help from the card's designer, I've discovered ways to increase the performance of existing TWGS cards by an additional 8% - 60%. This results in a computer that runs two to three times faster than a non-TWGS-enhanced Apple IIGS system.

This is the first of three articles in which I will describe how to install these enhancements. In this article, I describe how to install the simplest of the upgrades, which increases the TWGS cache memory from 8K to 32K. I recommend this enhancement for all TWGS owners. In Part Two, I will describe how to increase the card's processing speed from 7 MHz to 10 MHz. The cache upgrade I describe in this article is fully compatible with the upgrades to processing speed described in Part 2.

A Caveat

With almost 16,000 **NAUG** members reading these articles, you must recognize that I cannot provide individual technical support for these upgrades. Applied Engineering supports the cache upgrade with their usual technical assistance and warranty programs. Although I installed and tested each of the upgrades I describe in these articles, I cannot guarantee that these modifications will work on your system.

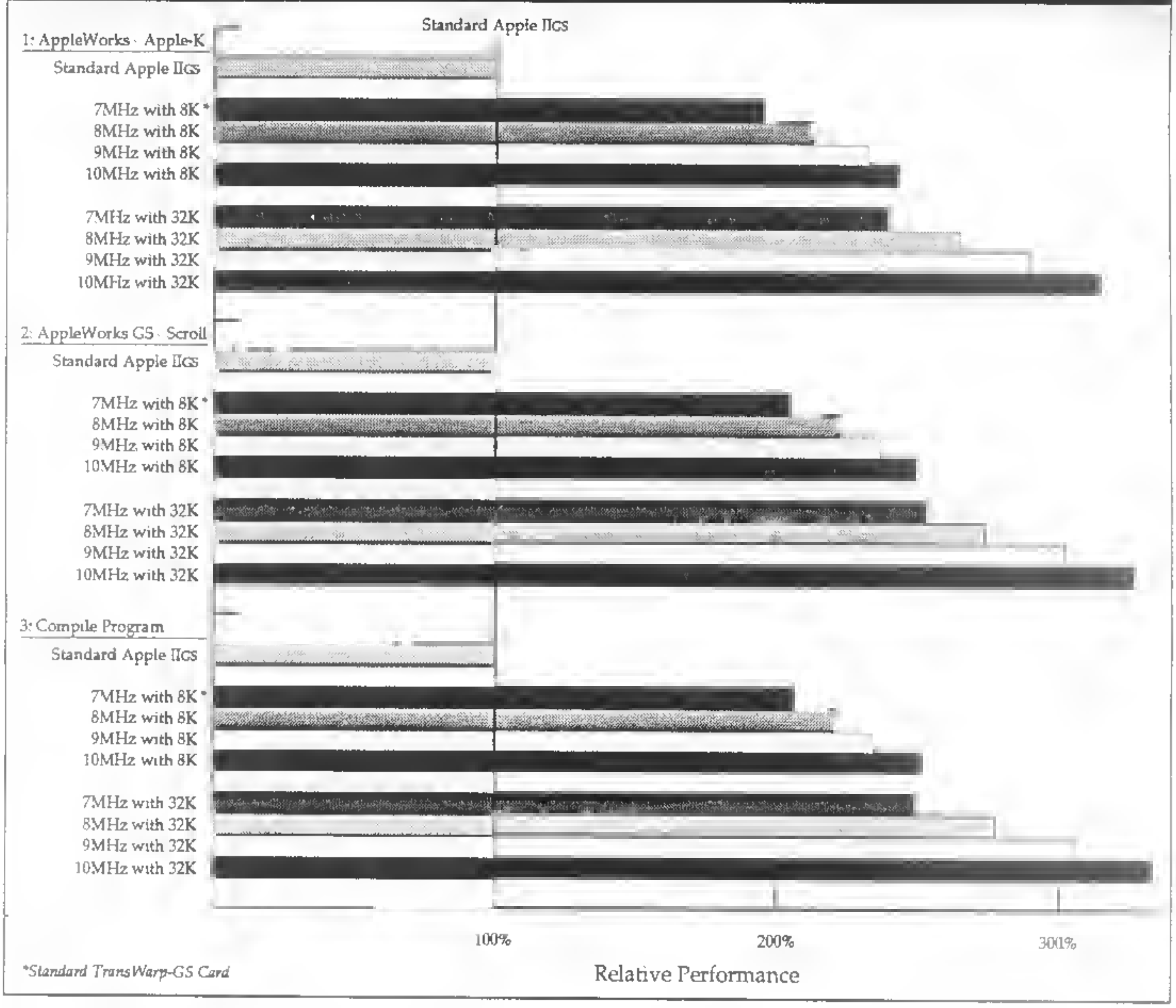
How to Get Enhanced Performance

There are two factors that determine the performance of your TWGS: The speed at which it processes instructions and the amount of high speed cache memory available on the card to execute those instructions.

Like most users, before I began this investigation I believed that accelerator performance was tied to processing speed. That is, I thought a 9 MHz accelerator would always outperform a 7 MHz accelerator. However, my tests revealed that the amount of cache memory on the card can have a significant impact on its performance. For example, I found that a 7 MHz TWGS with a 32K cache memory can outperform a 10 MHz TWGS with the standard 8K of cache. That is because a caching accelerator's performance is as dependent upon cache implementation as it is upon processing speed. (See the sidebar "Understanding Cache" for more details.)

Consequently, installing the cache upgrade kit is the single most effective enhancement you can make to any TWGS, no matter how fast its processor operates. Increasing the cache on the TWGS has all the advantages of factory approval and should work with any system which currently supports the TWGS. Fortunately, the cache upgrade also potentiates any increase in processing speed, so performance is improved exponentially when the two are combined on a single card. Consequently, anyone who is interested in installing the processing speed modifications I will describe next month should

Figure 1: Relative Performance of Apple IIGS Systems



install the cache upgrade first, to get the greatest benefit from increased processing speed.

Performance Increases

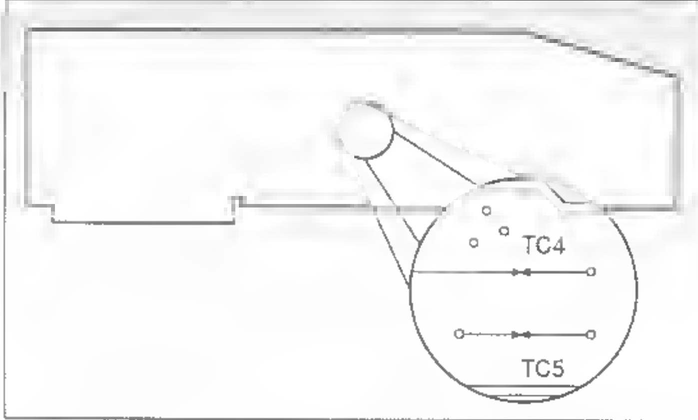
Figure 1 compares the performance of Apple IIGS computers equipped with TWGS cards that operate at different speeds and have different amounts of cache memory. The graph depicts the performance of these systems executing three different tests.

Test 1: Calculate the page breaks in a 218-page AppleWorks word processor document. This operation tests the TWGS's ability to manipulate large segments of RAM; the document occupied over 1500K of desktop memory.

Test 2: Scroll through a 39-page AppleWorks GS document. This task requires extensive updating of the screen display in the graphics environment, which is a significant shortcoming in the performance of IIGS systems.

Test 3: Compile 4800 lines of source code in MD-BASIC, a utility which runs under the 16-bit Orca-M development environment. This test involves repeated disk access and is thus not a perfect test of accelerator performance. Nonetheless, it shows that improving the performance of your accelerator will significantly accelerate processes other than sheer memory manipulation.

Figure 2: Back of the TransWarp GS Card



I conducted each test with an unaccelerated IIGS, with a IIGS equipped with a standard TWGS card (7 MHz and 8K of cache), with a 7 MHz TWGS and 32K of cache, and with cards operating at 8, 9, and 10 MHz with both the standard 8K cache and the upgraded 32K cache.

The Results

As you can see from *Figure 1*, installing a standard TWGS card more than doubles the speed of an unmodified IIGS system. Upgrading the cache on that card from 8K to 32K increases its speed an additional 22%. Upgrading both the speed of the card and the cache memory can increase TWGS performance by as much as 60%, leading to performance that is more than three times faster than that of an unenhanced IIGS system.

How to Increase Cache Size

You will need a wooden tongue depressor or a small screwdriver, an Xacto knife or single edge razor blade, and the Applied Engineering TWGS Cache Upgrade Kit to install this upgrade.

The process requires cutting two "traces" (the equivalent of wires) on your TWGS board and is not easily reversed. However, few owners will find any need to perform this reversal.

Follow these steps to increase the size of the cache on your card:

1. Turn off the power to your computer but leave it plugged into a grounded electrical outlet. Remove the case and touch the power supply inside the unit to ground yourself.
2. Remove the TWGS card from the computer.
3. The piggy back board is connected to the main TWGS by three 20 pin connectors. Remove it by rocking it back and forth until it comes free. If using your fingers proves too difficult, insert a tongue depressor or a screwdriver under one side of the piggy back board and gently pry as you rock the board. If you use a screwdriver, be certain to cushion its contact point with a piece of cardboard. Be careful not to damage the delicate traces that run underneath the piggy back board.
4. Locate the two traces at butterflies TC 4 and TC 5 on the back side of the TWGS board (see Figure 2). Use an Xacto knife or razor blade to scrape between the points of the butterfly until the connection is broken. Do not cut too deeply, there is a second layer of traces underneath the butterflies, and cutting into them could render the board inoperable. The second layer is not easily reached, but it is better to be cautious than aggressive.
5. Place the new piggyback board over the connectors on the main board and locate the resistor pack that protrudes from the TransWarp card. Remove the piggyback board and use finger pressure to bend the resistor pack toward the top of the TransWarp GS. Then put a piece of cardboard on the back of the piggyback board (that will protect your fingers from the exposed ends of the soldered components) and use finger pressure to insert the board.
6. Re-install the 32K TWGS in your system.

Testing Your Modified TWGS

Follow these steps to test the operation of your enhanced TWGS card:

1. Boot the system from your floppy or hard drive. If your system crashes or locks up, you did not completely cut the traces. Turn off your system, remove the TWGS card, and complete the cutting process.
2. Access the Control Panel and use the TWGS self-test routines to test the card. The test of the cache will take longer to execute; there is now four times as much cache memory to test. If you made a mistake, it will either not work at all, or

Understanding Cache

Both of the accelerators available for the Apple IIGS (TWGS and Zip GS) are caching accelerators. They read the contents of motherboard memory into a small area of high speed memory on the accelerator called its cache, which is why they are called caching accelerators. Although they are capable of accelerating any area of memory, these cards never accelerate more than a small portion of memory at any one time.

There are three phases in the operation of these cards, all of which consume time. First, the accelerator must capture the code it will accelerate. Second, the card's CPU executes the captured code at the accelerated processing speed. Finally, the accelerator must make any changes to motherboard memory indicated by the instructions processed in the cache. The third step is especially critical because the speed of motherboard memory is limited to 2.8, 2.6, and even a very slow 1.0 MHz, depending upon which area it addresses (2.8 for ROM areas, 2.6 for RAM areas, and 1.0 for screen display areas).

The TWGS incorporates features that improve all three operations.

Capturing and Executing

The TWGS divides its cache into two components called the "data area" and the "tag area". The data area contains the code it will accelerate; the tag area stores the address of the original code. The accelerator uses the information in the tag area to determine whether it has already cached the code it will execute, or whether it must capture that code first.

The IIGS system supports both 8-bit and 16-bit tags. Accelerators with an 8-bit tag limit the range of memory they can accelerate to a function of the size of the data area. For instance, an 8K data buffer might accelerate 1.5 megabytes of memory; a 16K data buffer might accelerate 3 megabytes, and so on. Thus, systems that use an 8-bit cache tag require more cache memory to accelerate all the memory in a large system.

The TWGS uses 16-bit tags which let it accelerate up to 16 megabytes of memory, no matter what the size of the data buffer on the card. Thus, adding more motherboard memory to a IIGS equipped with an 8K TWGS will not degrade its performance.

Unfortunately, the 16-bit tags require twice as many chips as the 8-bit system and results in a more expensive product. However, 16-bit tags are more efficient and more transparent to the user.

Every time the TWGS needs to execute some code, it checks the tag area to see if the code is already present. If the code is in the cache, the card executes the code. This is called a "hit". If the code is not in the cache, the accelerator captures the code from the motherboard. It stores the code in the data area and its address in the tag area. Then the TWGS executes the code. This is a "miss", because the capture and tag storage operations slow real world performance significantly.

A 100% efficient cache is one which never suffers a "miss". Regardless of whether you use an 8-bit or 16-bit tag, increasing the size of the data area in the cache increases the percentage of "hits", which is why the performance of the TWGS with a 32K cache is dramatically better than one with 8K of cache, even though processing speed is not changed.

Writing to Motherboard Memory

Many of the instructions executed in the cache issue orders that affect memory outside the cached instructions. The two techniques that handle this task are called "write through" and "write back".

"Write through" techniques halt processing until the system updates the memory outside the cache in accordance with the instruction just executed. This operation takes place at standard (unaccelerated) system speeds of 2.8, 2.6, or 1.0 MHz, depending on the area of the motherboard addressed. This process requires an additional delay because the DRAMS on the motherboard must synchronize their refresh cycles. This slow-down occurs frequently in all applications and can be a significant handicap to real world performance. However, write through technology is less complicated to implement, and can result in a less costly product.

"Write back" technology stores the instructions which order any change to motherboard memory in a special buffer on the accelerator at the accelerated speed. Later, they are written to the motherboard at the appropriate standard speed as a background process, while the accelerator continues to execute additional instructions at the accelerated speed. The TWGS uses multiple write back buffers to enhance its effectiveness and rarely slows down to standard speed.

Although write back is important for all data transfers from the TWGS to the motherboard, it is especially critical in accelerating screen displays, since the IIGS video memory cannot operate faster than 1 MHz (that keeps it compatible with Apple IIe applications). Thus, the TWGS handles the task of updating the screen in the background while you scroll through a large document. That leaves the TWGS free to continually process the code which orders the scrolling. This dramatically enhances the speed of operations that write to the screen, such as scrolling the screen with AppleWorks GS.

Applied Engineering Enhances TWGS

Applied Engineering now offers a factory approved, user installable kit which upgrades the TWGS's standard 8K of cache memory to 32K. The cache upgrade offers a 22% increase in the performance of a 7 MHz TWGS. When the upgrade is combined with modifications that increase processing speed on the TWGS to 10 MHz, the total increase in performance exceeds 60%.

The kit consists of complete instructions and a replacement piggy back board. The board includes ROM 1.7w32S (which makes it especially valuable to anyone with an early ROM who wants to install the processor speed enhancements I will describe next month) and SRAMs that are rated at 35 nanoseconds instead of the 45 nanosecond chips which are standard on the TWGS. The faster SRAMs should work reliably up to 10 MHz, which adds more value to the cache upgrade for anyone who is interested in attaining the fastest possible processing speeds from their TWGS card.

The TWGS Cache Upgrade Kit costs $109 directly from Applied and is available from many of their dealers.

[Applied Engineering, Box 5100, Carrollton, Texas 75011; (214) 241-6060.]

will fail one of the cache related self-tests, in which case you should cut the traces at TC4 and TC5 slightly deeper. When you cut them deep enough, everything should work smoothly.

The Cost of Customizing

The TWGS is a remarkable product, and Applied has recently reduced its price, making it an even more cost effective upgrade to your IIGS system. Now they are offering a reasonably priced 32K cache upgrade which I recommend highly to all TWGS users. The improvement you get with 32K of cache is dramatic in itself, and interacts with the enhancements to processing speed that I will describe in Part 2, for exponential improvements in performance.

At $109, increasing the cache on your TWGS might seem expensive. However, when analyzed as a function of the total cost of your computer, this enhancement, which offers more than a 20% increase in the processing speed of your entire system, is an excellent value.

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Accelerate Your TransWarp GS Card — Part 2

by John Link

In Part One of this series, I described how to upgrade the cache memory on an Applied Engineering TransWarp GS (TWGS) accelerator card from 8K to 32K. That modification significantly improves the performance of a TWGS without changing the card's 7 MHz processing speed. This article will describe how to increase the card's processing speed to 7.5, 8.0, 8.5, or 9.0 MHz. These are simple and relatively inexpensive changes. In Part 3, I will discuss how to get 10 MHz processing speed, a modification that is more complex and more costly than the others I described in this series.

Upgrades are Symbiotic

Increasing TWGS cache size and processing speed are separate upgrades; you do not have to install one to get the other to work. Nor does it matter which upgrade you install first. However, the cache and processing speed modifications interact with each other to generate exponential improvements in performance. As you can see from *Figure 1* in the previous article, you get a 22% improvement in performance when you increase the TWGS cache from the standard 8K to 32K. When you increase the processing speed of a standard 8K TWGS from 7 MHz to 9 MHz, you get a 15% improvement in performance. But the performance of the TWGS improves by 48% (instead of the "expected" 37%) when you install both modifications on a single card.

Thus, I recommend that you install the cache upgrade in conjunction with any of the processor speed modifications. *Figure 1* in the previous article describes the performance gains you get from each modification, and how the processor speed modifications interact with the cache upgrade.

What about the Warranty?

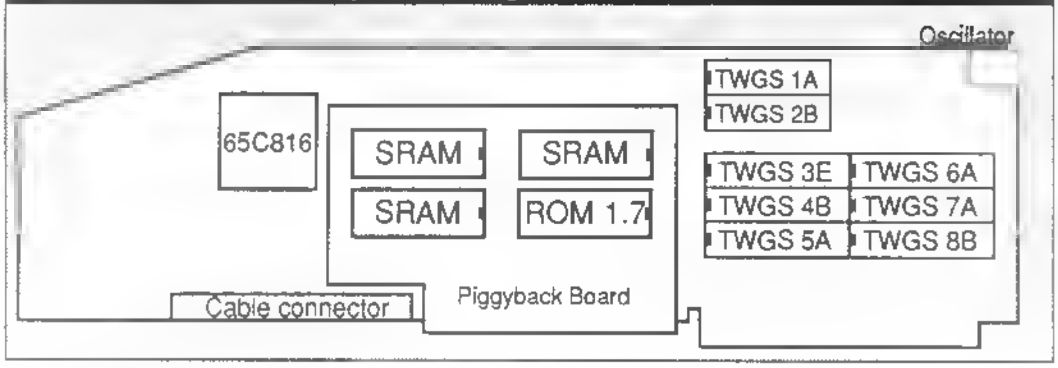
These changes do not void your warranty. If these enhancements do not work on your board, restore the original components to their respective sockets, and your card should once again operate at its standard 7 MHz speed. You should also restore the original components to the board if you return your card to Applied for repair. Applied often repairs boards by swapping a defective board for a new one, and you would lose your high speed parts in the process.

Qualifying Your TWGS ROM

If you installed the 32K cache upgrade I described in Part One, you have the latest version of the TWGS ROM. Otherwise, follow the directions in the manual and invoke the TransWarp Desk Accessory. If the eighth line of text on the first screen says "Revision 1.5" (or greater), your TWGS will run at speeds above 7 MHz. (Version 1.5 ROMs report false error messages in the speed self-test when the TWGS runs faster than 8 MHz. You can ignore those messages.)

If you do not have the appropriate ROM, I recommend that you install the TWGS Cache Upgrade Kit I described in Part One. That kit includes both the most recent ROM (version 1.7 is current) and the recommended 32K of cache memory. Alternatively, Applied will ship just the current ROM as a special order item for $20.00.

Figure 1: TransWarp GS Diagram



Replacing the ROM

The ROM is the only socketed chip on the piggyback board (see *Figure 1*). You can remove the ROM with a standard IC puller (they cost about a dollar at Radio Shack), or insert a small screwdriver under each end of the chip and carefully pry it out. I recommend the chip puller. If you use a screwdriver, make certain that you do not destroy any traces underneath the chip with the screwdriver tip. (One method to protect the traces is to use the edge of the piggyback board as the fulcrum for the first "prying" and then put a thin piece of cardboard under the screwdriver tip whenever it contacts the board.)

Removing the ROM will expose the 28 holes which held its pins. Applied uses a "zero profile socket mount" for the ROM; it is sometimes difficult to insert new chips into these mounts.

The new ROM comes with its pins spread out to facilitate its use in auto insertion machines. You will have to bend these pins to the vertical position so they fit into the socket without deflecting underneath the chip.

Put the new ROM on its side with one row of pins resting on a flat table; then rotate the chip until the pins are almost vertical. Repeat this process for the other row of pins. Put the chip over the socket and make certain that all the pins line up correctly. Repeat this procedure until the pins line up. Do not force a misaligned chip into a zero profile socket, or you may bend one or more of its pins underneath the chip.

Finally, note the location of the notch on the ROM chip in *Figure 1*. Install the new ROM with that orientation.

If coping with a zero profile mount seems too difficult, you can buy a standard 28 pin low-profile socket (Radio Shack part #276-1997) for less than a dollar. Insert the new ROM into the low-profile socket by inserting the pins on one side of the IC slightly, then rotate the chip so the second side lines up. Then press the chip in place. You still must be careful not to bend a pin underneath the chip, but it is much easier to insert a chip into a low profile socket than into a zero profile mount. Note the location of the notch and insert the entire package into the TWGS. The low-profile socket is easy to insert into the card.

Qualifying Your TWGS Cable

Some TWGS owners experience problems with the cable that attaches the TWGS to the motherboard. Continuity tests show that these cables pass a small test current, but the cables are unreliable in actual use. This problem generally appears after you stress the cable by removing and reinstalling the TWGS. If you experience intermittent failures of an unexplained origin that go away when you replace the TWGS with your original 65C816 CPU, contact Applied for a replacement cable. Applied ships an improved cable with all boards manufactured after November 1, 1990.

8 MHz for Five Dollars

The processing speed of your TWGS is determined by an oscillator, which is a timing device that determines how fast the TWGS executes the instructions in its cache. It takes four cycles of the oscillator for the processor to execute a single instruction. Thus, a TWGS card with a 28 MHz oscillator processes instructions at 7 MHz.

Check the speed printed on the oscillator (see *Figure 1*). Applied shipped TWGS cards with 28 MHz and 25 MHz oscillators which operate at 7 MHz and 6.25 MHz respectively. Owners of 7 MHz TWGS cards can usually increase the speed of

Modifying a Full TTL Oscillator

Both the standard and hard-to-find mini-oscillators use four pins arranged in the same relative position on the part. To use the larger oscillator with the TWGS, you must solder extensions onto the two lower legs, then bend the extended legs so they fit into the smaller 8-pin socket used by the TWGS.

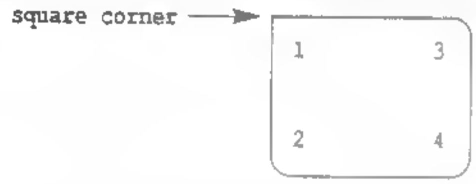
You will need the oscillator, a low wattage soldering iron (e.g., Radio Shack's 25-watt #64-2070; $6.49), electrical rosin core solder (not acid core), one large light emitting diode (less than $1.00 at Radio Shack and other electronic stores; you will use the wires on the LED as the extensions to the legs on the chip), a nail clipper or small scissor, a short piece of electrical tape, and small needle-nose pliers.

The diagram in *Figure 2* shows the layout for the legs on the oscillator, using the one square corner on the chip as the reference. Leave pins 1 and 2 alone. You will solder the extensions onto pins 3 and 4.

Follow these steps:

1. Pre-heat the soldering iron for ten minutes.
2. "Tin" each leg of the LED as follows:
   A. Separate the legs of the LED and hold the unit by the plastic housing.
   B. Apply the soldering iron and a minimum amount of solder to one leg until it flows.
   C. Repeat this process for the other leg.
3. Repeat step #2 and tin the tips of legs 3 and 4 on the oscillator. Use enough heat to cause the solder to flow, but avoid overheating.
4. Lay the oscillator on the table with its legs pointing up. Grasp the LED by its plastic end, and hold the LED against leg 3 on the oscillator while applying heat from the soldering iron. When the solder flows, remove the iron, but continue holding the LED leg against the oscillator leg for a moment until the solder sets.
5. Clip off the leg just below the plastic end of the LED.
6. Repeat this process for leg 4 on the oscillator.

Figure 2: Legs on the Oscillator



7. Trim the soldered extensions so the legs are approximately twice as long as the original legs.
8. Use the needle-nose pliers to bend the extended legs in an "S" curve so they fit in the holes on each side of the 8-pin socket. Be certain that the bent leg does not contact the metal case of the oscillator. (Contact with the metal case will cause the TWGS to fail upon boot up but will not damage the board or computer. Once you correct the problem, your computer will work normally.)
9. Attach a small piece of electrical tape to the bottom of the oscillator before you insert it in the TWGS. That will keep the modified legs from contacting the oscillator case when you insert the oscillator in the TWGS card. Do not omit this step.
10. Insert the oscillator in the appropriate TWGS socket.

their system just by changing the oscillator. Owners of 6.25 MHz accelerators will also have to replace the CPU to get any processing speed improvements.

Replacing the oscillator is the easiest and least expensive way to increase the processing speed of your card, and many vendors sell suitable oscillators for less than $5.00. Almost all 7 MHz TWGS cards will run reliably at 7.5 MHz if you substitute a 30 MHz oscillator for the 28 MHz part originally on the card. My work suggests that approximately 80% will run reliably at 8 MHz with a 32 MHz oscillator. Some will work at 8.5 MHz, using a 34 MHz oscillator (but 34 MHz oscillators are hard to find), and a few will run at 9 MHz, using a 36 MHz oscillator. As a practical matter, anyone who wants 9 or 10 MHz processing speed should also plan to replace the CPU, as described below.

The TWGS uses a hard-to-find "mini TTL" or "1/2 TTL" oscillator that fits into an 8 pin socket. Radio Shack does not carry oscillators, so you should check with a specialized electronics store. (Take your original oscillator to the store if you are uncomfortable describing what you need.) If you

Sources of Supply

Applied Engineering	Western Design Center	JDR Microdevices
Box 5100	2166 East Brown Road	2233 Branham Lane
Carrollton, TX 75011	Mesa, AZ 85203	San Jose, CA 95124
(214) 241-6060	(602) 962-4545	1-800-538-5000

cannot find the mini TTL oscillators, JDR Microdevices sells standard "full TTL" oscillators that you can modify to fit on the card. (See the sidebar entitled "Modifying a Full TTL Oscillator" for the details.)

Installing the Oscillator

You do not have to remove the TWGS card to upgrade the oscillator. Turn off your computer but leave it plugged into the wall receptacle. Remove the cover and ground yourself by touching the power supply. Remove the oscillator by gently pulling it straight off the card with just your fingers. Note that the square corner of the oscillator (which is also marked with a dot) goes in the upper left hand corner of the socket, and that the oscillator has only four legs; the middle four holes in the socket are not used. Insert the faster oscillator into the socket and test your system.

RamKeeper owners who cannot boot their systems with the accelerated TWGS will have to reinstall and reconfigure their AEROM disks as described in the manual. Set the system and TWGS speeds to "Normal", then reinstall and reconfigure your RamKeeper. Finally, restore the TWGS to "TransWarp" and the system speed to "Fast", and test your system.

This procedure works because the 7 MHz processor on your card passed a test which proves it will operate reliably at 7 MHz under the worst possible conditions. These include high ambient temperatures and low voltages on the 5 volt line that supplies the card's power. In some cases, the chip was not even tested for its ability to work at a higher speed, and may well have passed a higher test speed. Your system's conditions may be more optimal than those for which the TWGS was designed; your chip may operate faster than its 7 MHz rating, or both. By installing a faster oscillator, you are in effect testing your chip for higher speed operation in your particular system. Many of them will pass.

Upgrading to 9 MHz

The TWGS uses PLCC 65C816 (44 pin) chips for its CPU. Western Design Center sells high speed versions of the 65C816 for $95.00 as "engineering chips" (Part # W65C816PL-ENG). These chips are direct replacements for the original CPU on the TWGS. *[Ed: NAUG members can get these chips from Western Design for $71.25. Identify yourself as a NAUG member and supply your NAUG ID number when you order.]* These high speed processors will run reliably at 9 MHz, and most will work at 10 MHz if you make the modifications that I will describe in next month's article. (Those who ultimately want to achieve 10 MHz performance will suffer no harm by buying their engineering chip this month and by first installing the 9 MHz upgrade.)

Western Design ships each engineering chip with its own shmoo plot. You do not have to understand the shmoo plot to use the chip, but the next article will describe how to interpret the information on the plot that came with your chip.

To achieve 9 MHz operation, you will need both a high speed 65C816 and an oscillator rated at 36 MHz.

Theoretically, some of the socketed parts on a standard TWGS should not perform reliably above 8 MHz. However, all three of my test boards have been running reliably at 9 MHz for more than four months, using nothing but standard parts. I am confident that virtually all users will be able to achieve 9 MHz performance, especially if their system is equipped with a fan. However, it is not possible for me to absolutely guarantee that everyone will experience my level of success.

Installing the New CPU and Oscillator

Follow these steps to modify your TWGS for 9 MHz operation:

1. Turn off your computer, remove the cover, and ground yourself by touching the power supply.
2. Remove the TWGS by reversing the installation procedure described in the TWGS manual.

3. See *Figure 1* for the location of the processor socket, which surrounds the 65C816 chip. Straighten a fairly stout paper clip and bend the last half inch so it forms a 90 degree angle with the shaft.
4. Each corner of the processor socket has a slot that is wide enough to admit a paper clip. Insert the bent end of the paper clip into one of the four slots in the socket until it is underneath the chip. Gently pry upward, using the paper clip as a lever; then repeat the process in each corner until the chip is free.
5. PLCC chips are "keyed" with one corner cut off. Line up the new CPU with this cut off corner positioned above the upper left hand corner of the socket (viewed with the TWGS facing you). Press the new chip down carefully using only finger pressure until it is fully seated in the bottom of the socket.
6. Replace the oscillator with one rated at 36 MHz using the procedure described above.
7. Reinstall the TWGS. Be certain that the cable is connected securely to both the IIGS motherboard and the TWGS; loose connections at these points can cause an otherwise successful modification to fail.

Testing Your Modified TWGS

9 MHz: You should not have to test the 9 MHz upgrade extensively, since engineering 65C816 chips should run this fast with ease. Immediately after booting up, run the TWGS self-tests according to the instructions in the manual. TWGS cards equipped with version 1.7 ROMs should not fail any test. Version 1.5 ROMs will fail the speed test, but that is not significant. Use your system to do unimportant work for four hours and once again perform the self-tests. After four hours, you can proceed with normal use. Back up your work frequently until you are confident that your upgraded TWGS performs reliably.

Simple Oscillator Swap: The simple oscillator replacement requires a more cautious approach, since you are pushing your CPU to its limit. Use the test method I described for the 9 MHz upgrade, but extend the continuous run time to 48 hours, and save your important work frequently until your are certain your faster TWGS performs reliably.

Applied Engineering and Western Design Center both say that running normal software after the warmup is the best way to confirm that the upgraded board is reliable. I found one case of an over-accelerated 65C816 (on a TWGS modified only by replacing the oscillator with a faster version) that passed all the self-tests, but which was not entirely reliable after being left powered up for 48 hours.

What If It Fails?

Start by installing a system fan if your high-speed computer doesn't operate reliably. The cooler your system, the more reliably it will work at these higher speeds.

If you are using a modified full TTL oscillator, make certain that you installed the small piece of electrical tape described in step #9 of the sidebar.

If neither of these fixes solves your problem, replace the oscillator with one that operates slightly slower, until you achieve reliable operation. You can also replace your power supply with a specially configured heavy duty unit from Applied Engineering; I will describe this last remedy in Part 3.

Conclusion

If you follow these suggestions, 80% of all TWGS owners can upgrade their computers to operate at 8 MHz for the $5 cost of a new oscillator. If you already have a fan, it costs a NAUG member less than $80 to upgrade to a 9 MHz system. This is quite reasonable, considering the overall cost of your IIGS computer, and this is the upgrade that is most likely to succeed. Thus, I recommend the 9 MHz upgrade to anyone who does not want to get involved in uncertainties.

The next article will describe how to accelerate your system to 10 MHz. Those techniques will build upon the 9 MHz upgrade described here.

[John Link is an AppleWorks consultant and the developer of SuperPatch and LockOut. The author and NAUG extend special thanks to Steven Malechek of Applied Engineering for his help with this article.]

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Accelerate Your TransWarp GS Card — Part 3

by John Link

The first two articles in this series described how to install a 32K cache upgrade in an Applied Engineering TransWarp GS (TWGS) accelerator card and how to increase the card's processing speed to 9 megahertz. This article describes the ultimate upgrade; one that lets you run your Apple IIGS system at 10 megahertz. *Figure 1* in the first article in this series includes a graph that depicts the system performance you can achieve with the 10 MHz and 32K cache upgrades. As you can see from that figure, you get the greatest benefit by installing both of these enhancements.

Although this is the most complex of the TWGS upgrades, I installed it successfully on three randomly selected boards. None the less, you must realize that you are pushing the engineering-grade 65C816 to the very edge of its capabilities. These procedures are for users who are willing to experiment without a guarantee of success. Work carefully when you make these modifications; you will void the warranty if you damage your board or install a chip incorrectly.

TWGS Limitations

The basic circuitry of the TWGS will work at speeds in excess of 10 MHz; I know of boards that run reliably at 12 and 13 MHz. However, most of the socketed parts on the TWGS are rated for 8 MHz operation, and Applied Engineering cannot warranty that the socketed components will work at speeds faster than their 8 MHz rating. Fortunately, most manufacturers under-rate the parts they supply to Applied, so many TWGS cards will work at 10 MHz with standard parts. If you want to use parts rated to work at speeds faster than 8 MHz, Applied will supply a set of the four most critical GALs (Generic Array Logic chips) as a special order item; contact the company for prices. *[Applied Engineering, Box 5100, Carrollton, Texas 75011; (214) 241-6060.]*

All versions of the TWGS ROM from version 1.5 forward will work at 10 MHz. See the previous article for procedures that describe how to qualify and upgrade your ROM.

Overcoming the 10MHz Barriers

Install a high speed processor and oscillator: Most 65C816 processors used on a TWGS will operate reliably up to 8 MHz; you need a high speed 65C816 CPU and 40 MHz oscillator to achieve 10 MHz operation. The previous article describes these special components.

Use a fan: A fan dissipates some of the internal heat which builds up as you run the CPU faster. That adds to the reliability of your system. You will need a fan if you want to accelerate your TWGS to 10 MHz.

Increase system voltage: Initially, both the 65C816 engineering chips I tested ran reliably at 9 MHz with several standard IIGS power supplies. One of the processors began to develop problems after six weeks of reliable operation. (See the sidebar "Burn-In and 9 MHz" for more details.) Both chips were reliable at 10 MHz when I used an

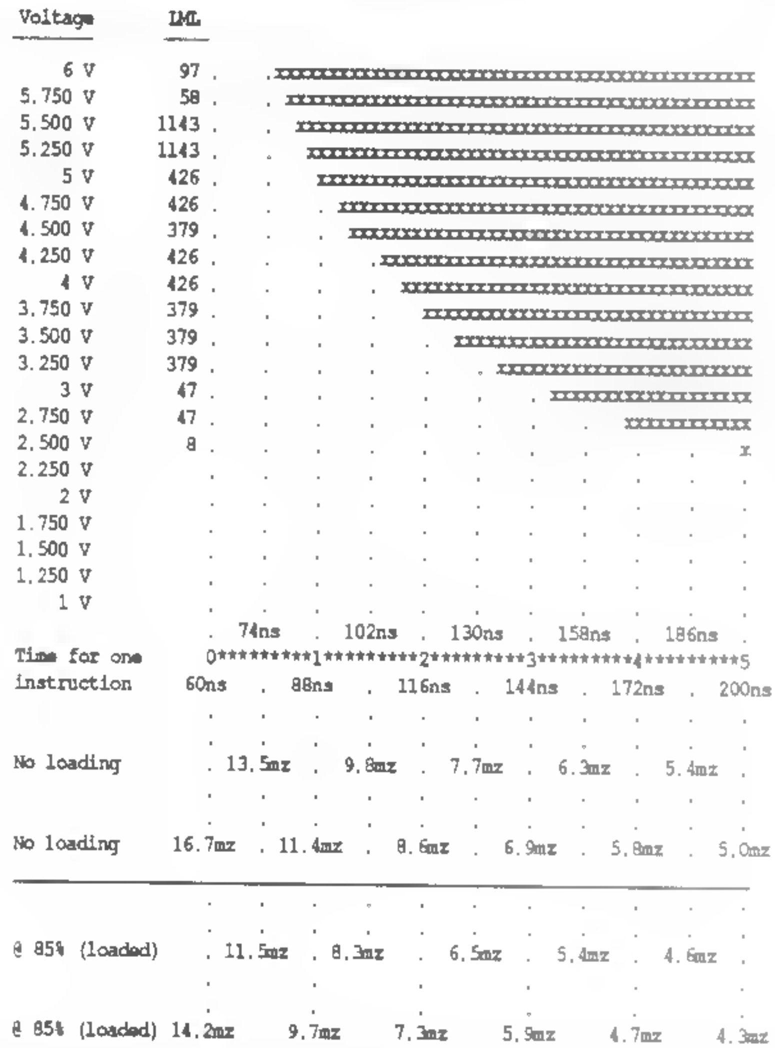
Ten Megahertz Barriers

Western Design includes a "shmoo plot" (see *Figure 1*) that graphs the results of a test which they run on every engineering-grade 65C816. A table at the top of each plot (which I deleted from *Figure 1*) includes the data used by the operator for the test; you do not need to understand that data to interpret the plot. Likewise, the "LML" column on the plot refers to the "Lower Memory Location" where the test registered its first failure. The tester uses the LML and it has no bearing on using the chip with a TWGS.

The X's on the each line represent the number of nanoseconds it takes to execute one instructional cycle; the fewer the nanoseconds, the faster the processing time. To translate this figure into the more commonly understood "megahertz", divide 1000 by the time required to execute one instructional cycle. I performed this calculation for each major division in the plot and entered those values underneath the graph in an area I labelled "No loading". That tells you the number of instructional cycles the chip can execute each second. Thus, a chip operating at 10 MHz is twice as fast as a chip operating at 5 MHz.

A chip's maximum speed is determined in great part by the voltage supplied for its operation and by the speed and current used by other components connected to its circuits. The vertical scale in the shmoo plot represents voltage from 1.0 to 6.0 volts. The first "X" on each line indicates the fastest speed at which the chip will process instructions reliably at that particular voltage if there is no interference from other factors.

Figure 1: Typical Shmoo Plot



The TWGS gets the voltage for its CPU from pin 25 of the edge card connector, which is nominally supplied with 5.0 volts. (The standard 65C816 on the IIGS motherboard receives the same current found at pin 25 of the edge card connector.) As you can see from *Figure 1*, the higher the voltage available to the processor, the faster the 65C816 can operate reliably. The sample plot suggests that this processor can operate reliably at approximately 13 MHz if it is supplied with a 6.0 volt current.

Western Design tests the engineering processors under optimal

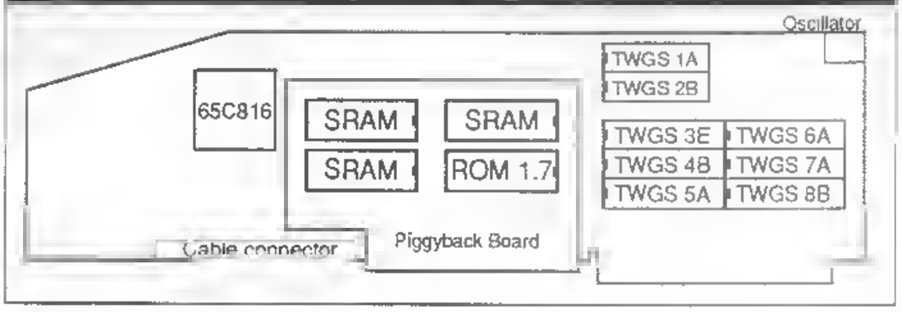
conditions by using the 65C816 in a circuit that places minimal current loads on the chip's pins. The TWGS connects the 65C816 to additional circuits that substantially increase this loading, and therefore increase the time it takes to process instructions reliably at any given voltage. Further, the test does not consider the degradation of the chip's performance that inevitably occurs after a month or so of use (see the sidebar "Burn-In and 9 MHz").

As a rule of thumb, you can expect a processor installed on a TWGS to perform reliably at 85% of its "No load" designated speed. Thus, I added the 85% loaded values to the shmoo plot in *Figure 1*.

Once you make the adjustment for the loading, you can see that a typical engineering chip will not run reliably at 10 MHz when installed on a TWGS unless you increase the voltage beyond the standard 5 volts.

In addition, current 65C816 chips cannot execute certain instructions reliably when operating beyond 4 MHz; circuitry on the TWGS intercepts those instructions and allows extra time for their execution. However, when you reach 10 MHz, additional instructions do not execute reliably in 16-bit mode. The TWGS does not intercept these instructions unless you use a revision E or later TWGS 3 GAL.

Figure 2: TransWarp GS Diagram



Applied Engineering heavy duty power supply that I adjusted to yield 5.25 volts. After several months of intense use (averaging 12 hours per day) one became unreliable at 5.25 volts and required 5.5 volts to run at 10 MHz.

The standard IIGS power supply, which provides a nominal 5.0 volts to the CPU on the TWGS, is not easily adjusted; you must remove and replace soldered parts to change its output. Adjusting the output from the AE power supply is not as difficult, but involves exposure to potentially lethal current; thus, I will not describe how to perform this operation. However, Applied will sell NAUG members a power supply that provides 5.25 volts for only a nominal charge over the basic cost of the unit. You should install one of these power supplies in your system before proceeding with the 10 MHz modification.

Use new GALs: As indicated in the sidebar "10 Megahertz Barriers", some operations are unreliable when you drive a 65C816 processor faster than 4 MHz. GAL chips on the TWGS intercept these instructions and add additional cycles when they execute to provide reliable operation at faster speeds.

You need a revision E (or later) #3 GAL to operate the TWGS at 10 MHz; Applied programmed that chip to compensate for certain 16-bit instructions that do not execute properly at 10 MHz. (See *Figure 2* for the location of the TWGS 3E chip.)

The extra voltage from the special power supply increases the reliable operating speed of the standard TWGS GALs so that some will work at 10 MHz. However, success on any given board depends upon all eight GALs working at the higher speed. One of the boards I tested did not work at 10 MHz until I installed the high performance GALs .

You can order the TWGS 3E GAL directly from Applied as a single item, but I suggest that you get the set of four high performance GALs (#2, #3, #4, and #5) if you are going to the trouble and expense of ordering. Those high performance parts increase the likelihood of the success with your 10 MHz upgrade.

Replacing a GAL is similar to replacing a memory chip. Use *Figure 2* to locate the chips, remove the originals with a standard chip puller or small screwdriver (be careful not to damage any nearby traces),

and press the replacements in the sockets with your fingers. Orient the chip in the proper direction by placing the notch as shown in the diagram. Save the original GALs and reinstall them on your TWGS if you return the card for warranty or other repairs. Otherwise, you will lose the high speed GALs if Applied substitutes a new board for the one you return.

Use high speed SRAMs: Applied uses 45 nanosecond (ns) SRAMs on the TWGS. Because they tend to be under-rated, and because the higher voltage from the special AE power supply increases their maximum speed, many will work at 10 MHz. (I found all the standard 45ns SRAMs I tested were reliable at 10 MHz.) However, your chances of successful 10 MHz operation will increase substantially if you install the 32K cache upgrade which includes 35ns SRAMs. Some 10 MHz upgrades will require 25ns SRAMs. In that case, simply replace the socketed 35ns SRAMs on the back of the upgraded piggy back board with the faster SRAMs.

Bring It All Together

To get 10 MHz speed, you must approach your TWGS and IIGS system as a totality. Every time you raise the maximum speed of any component on your TWGS, you make it easier for the CPU to perform reliably at a higher speed. Thus, faster GALs and SRAMs allow greater latitude for the CPU to do its job. The increased voltage from the AE power supply increases the maximum reliable operating speed of all components; it is a universal tonic for chips that cannot keep up. Likewise, a fan gives every component a greater range of operating speed by evacuating the heat which causes them to become unreliable.

Theoretical and Practical Limits

Theoretically, you can modify a TWGS to run at 12 or 13 MHz with currently available 65C816 chips. However, that involves adding a voltage regulator to the board and altering the circuitry so the CPU on the TWGS gets its power from the 12 volt line stepped down to 5.75 volts.

Supplying 5.75 volts to the CPU causes it to generate internal heat that will significantly interfere with its reliability and will shorten its life. You can add delay cycles to the operations affected by the heat, but that would nullify most of the gains you achieve by increasing the processing speed. A better alternative is to connect a cooling unit directly to the CPU, which also decreases the negative effects of loading the chip with additional current from other circuits on the TWGS. That costs about $150, occupies two or three slots immediately adjacent to the TWGS, and further taxes the IIGS power supply.

A better solution for performance beyond 10 MHz is to use a 65C816 chip that is engineered for higher speeds. Western Design Center says it is working on such a chip, but was not able to furnish a prototype for this article. We can only hope that their goals are realized and that production models of faster chips become available.

"Burn-in" and "Burn-out"

The life of a computer chip is completely down hill; the only question is how fast it declines, and how soon. A chip is at its best when it is new. After 4-8 weeks of normal use, there is a noticeable decline in the maximum speed at which the chip can operate reliably.

A "good" chip stabilizes at a level consistent with its specified range of operation and performs reliably for a long but indeterminate period of time. Such a stabilized chip is said to be "burned in". Eventually, rapid decline sets in once again, and the chip "burns-out" and fails.

A "bad" chip never stabilizes but instead continues to decline. That is why bad chips usually show up during the first few weeks you own your equipment.

The remedy for a burned-in chip that will no longer run at a higher speed is to increase the voltage available for its operation. The special AE 5.25 volt power supply will resolve most of these problems, assuming the chip has not entered the final failure portion of the curve.

Performing the Upgrade

Start by installing a 5.25 volt AE power supply, a system fan, and a TWGS 3E GAL chip if you need it. Then change the processor and install a 40 MHz oscillator following the instructions for the 9 MHz upgrade I described in the previous article. That article presents the necessary detailed instructions.

Test your system by using the procedure I described last month for the "Simple Oscillator

Computing Efficiency

I once assumed that there was a linear relationship between processing speed and computer performance; that is, I expected each doubling of processor speed to result in a doubling of throughput. However; my tests show that you gain somewhat less performance with each increase in processor speed. That is caused by the nature of caching accelerators and the speed limitations built into the IIGS motherboard, especially the 1.0 MHz limit for the video firmware. When processing speed reaches 17-20 MHz, further acceleration might not yield a difference that is detectable in normal use.

How to Tell if Your CPU is Failing

Once you've upgraded your TWGS to 10 MHz, you should know how to tell if it starts to fail.

The 65C816 has its greatest difficulty while executing 16-bit instructions. Thus, the chip is most likely to fail when running 16-bit GS/OS applications such as AppleWorks GS and HyperCard IIGS. (Note that AppleWorks uses 16-bit instructions when you boot the program on a IIGS or run the spreadsheet module on IIGS systems. Therefore, failures in those operations can also indicate deterioration of your high speed CPU.)

If these problems occur, replace the fast oscillator with the original 28 MHz unit. If that cures the problem, you probably have a CPU that can no longer work at the higher speed at the current voltage. I suggest that you increase the system voltage or change the oscillator and settle for slower operation.

Failures that occur regularly in both 8-bit and 16-bit programs suggest either a rapidly deteriorating CPU or the inability of some other component on the TWGS to work at the current voltage. SRAMs and GALs are the most likely culprits. The 5.25 volt power supply may help them as well.

Swap". If your system fails, you should install the 32K cache upgrade I described in the first article in this series. That upgrade enhances performance significantly and provides faster SRAMs that let the CPU operate more reliably at higher speeds.

If your system fails after you install the cache upgrade, replace the #2, #3, #4, and #5 GALs with high performance versions.

If neither procedure succeeds, replace the SRAMs on the 32K cache piggy backboard with 25 or 15ns versions, or take your system to a qualified technician and raise the output from the AE power supply to 5.5 volts. That exceeds the range of recommended voltages for the IIGS and you make this change at your own risk. However, I have operated my system at 5.5 volts without any apparent harm.

The final practical solution is to replace the four remaining GALs (#1, #6, #7, and #8) with high speed versions. Beyond that, you must consider extreme measures (such as adding a cooling unit) which are beyond the scope of this article. Otherwise, you can wait for Western Design to offer better 65C816 processors. Until then, replace your 40 MHz oscillator with a 36 MHz version and enjoy 9 MHz performance.

Final Thoughts

Reaching 10 MHz requires a new processor, a 40 MHz oscillator, possibly one or more new GALs, a new power supply, a fan, and possibly faster SRAMs. The total expense for these items is significantly greater than that required for a 9 MHz upgrade, and even then, successful 10 MHz performance is not guaranteed.

Nonetheless, upgrading to 10 MHz will appeal to users such as myself, who derive satisfaction from having the highest attainable performance from their system. In addition, the heavy duty power supply and fan required to achieve 10 MHz will add to the reliability and longevity of any system.

[John Link is an AppleWorks consultant and the developer of SuperPatch and LockOut. The author and NAUG extend special thanks to Steven Malechek of Applied Engineering for his help preparing this article.]

[NAUG members can buy the engineering-grade 65C816 processor directly from Western Design Center for $71.25 (list price: $95) plus shipping. Contact Deb Lamoree at Western Design (602) 962-4545 and identify yourself as a NAUG member to get the details of this offer.]

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About NAUG:

The National AppleWorks Users Group (**NAUG**) has one mission – to help AppleWorks users. **NAUG** is the world's largest association of Apple II users with more than 15,000 members in the United States and 44 other countries.

NAUG members receive the ***AppleWorks Forum***, a 36-page monthly newsletter that describes tips, techniques and hints to help users get more from AppleWorks. The ***AppleWorks Forum*** includes other articles of interest to AppleWorks users, including news of product releases and reviews of AppleWorks enhancements and AppleWorks-compatible software.

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